B1 – Size and shape of the Earth

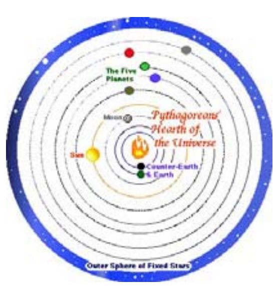
B1.1 Is the Earth flat?

Speculations …….

- Once believed that the Earth is flat and that ships could sail over the edge.
- View persisted into the Middle ages and was an issue in recruitment for Columbus.
- The Flat Earth Society still alive and well http://theflatearthsociety.org/ and describe the Earth as "*being a disk with a circumference of about 78225 miles and a diameter of 24900 miles. The sun and moon are both disks about 32 miles in diameter …and are about 3000 miles above the Earth, and the stars about 100 miles above the sun and moon. The Flat Earth Society also maintains that the Earth is accelerating upward at a rate of 9.8 m/s², thereby simulating gravity. This upward momentum is caused by the "Universal Accelerator", a vague term used by the Society to describe a force that originated at the Big Bang and caused the Earth to speed upwards. Gravity cannot exist on a flat Earth since the disc shape would eventually collapse on itself. However, other planetary bodies such as the moon and the sun have gravitational pulls, causing the gravitational force on an object to decrease as it increases in altitude. This also allows spacecraft to orbit.*" http://en.wikipedia.org/wiki/Flat_Earth_Society

B1.2 Historical perspective

- Early Greek view was that the world was surrounded by *Oceanus*, origin of all rivers.
- Anaximander (600 B.C.) – cylindrical earth surrounded by celestial sphere



- Pythogoras (582-507 B.C.) believed the Earth was a sphere, which was considered the most harmonious geometric shape.

- Aristotle (384-322 B.C.) described observations that supported the theory that the Earth was a sphere. These included (1) the fact that the shadow of the moon is circular in lunar eclipses (2) constellations were higher in the sky as one traveled south.

- More historical details of ancient Indian, Armenian and Islamic studies can be found in the article : http://en.wikipedia.org/wiki/Spherical_Earth

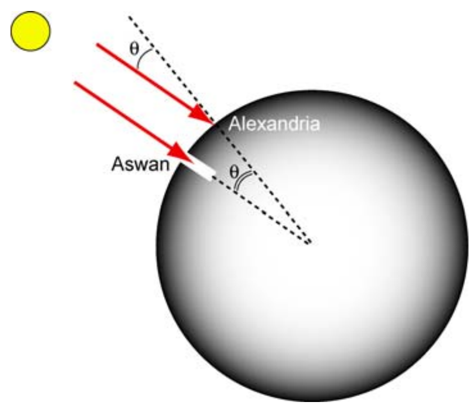
Observations that suggest the Earth is a sphere

- Mountain peaks lit by the Sun after sunset.
- Ships disappear below the horizon as they sail across ocean.
- The moon looks like a disk. Is the Earth the same shape?
- The Earth casts a circular shadow during lunar eclipses.

B1.3 Quantitative approach to computing the radius of the Earth

Eratosthenes (275-195 B.C.)

Estimated size of Earth from observations that the elevation of the sun varied with position on the Earth's surface in Egypt.



Measurement 1: Angular distance Aswan - Alexandria

On the summer solstice, the sun was overhead in Aswan, since it illuminated a deep well. On the same day, the sun was at an angle of 7° 14' to the vertical in Alexandria.

Measurement 2 : Distance on ground Aswan – Alexandria

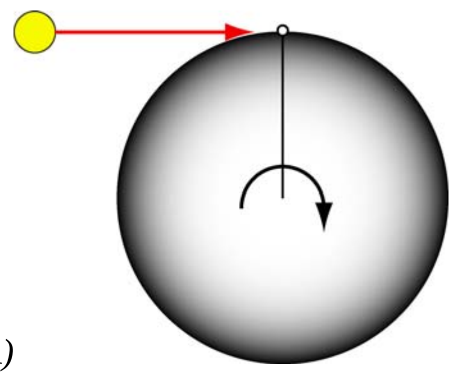
The distance Aswan-Alexandria was estimated at 5000 stadia = 925 km

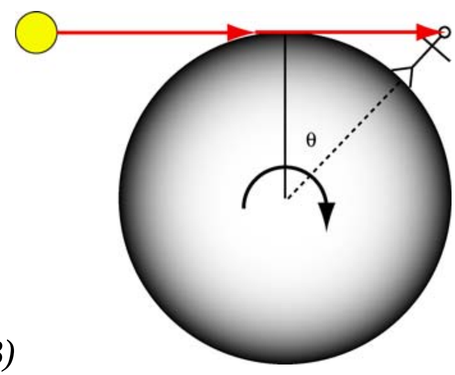
Combining these measurements, can show that the circumference of the Earth = 360 *925/7.23 = 46058 km**.** Correct value = 40030 km. Error = 15%

Jean Picard (1620-1682) : Measured the length of ~1 degree of latitude in France in 1669-70 and obtained a value of 6329 km for the radius of the Earth. Polar radius known to be 6357 km which is an error of 0.4% (http://en.wikipedia.org/wiki/Jean_Picard)

Another approach - the double sunset

- A seated observer watches the sunset over the horizon (A) at the Equator. As soon as the sun sets, he jumps to his feet and enjoys a few extra seconds of sunlight before the sun sets again (B).


(A)



(B)

The observer was 2 m tall and the two sunsets were separated by 7.5 s. Through what angle (θ) does the Earth rotate in this time?

θ = ______ degrees = ______ radians

The radius of the Earth can be shown to be $R = \frac{h}{\theta^2}$ where the angle θ is measured in radians and the observer is *h* m tall.

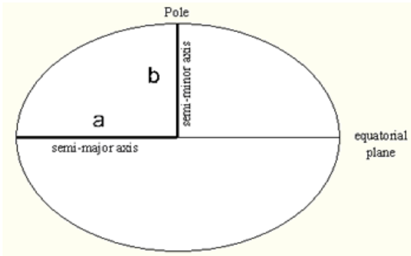
R = _______ m

B1.4 Non-spherical Earth

It was soon realized that the Earth was not a perfect sphere. **Jean Richer** (1620-1682) was a French astronomer who made observations in 1671 from the island of Cayenne in French Guyana. In addition to measuring the distance of planet Mars from Earth, he also noted that a pendulum swung **slower** on Cayenne Island than in Paris. He deduced that this was because gravity was weaker on Cayenne, which implied that Cayenne was further from the centre of the Earth than Paris.

Isaac Newton (1642-1727) suggested that the Earth was an oblate spheroid because it rotates - somewhat flattened at the poles.

A debate followed about whether this was true, because measurements were not very accurate. Surveys in Peru (equator, 1735-43) and (equator, 1735-43) showed that flattening occurred as suggested.



The deformation is now described by the International Reference Ellipsoid. This is the shape the Earth would have if it's composition was uniform. A number of ellipsoids have been defined as data quality has improved.

Ellipsoid reference	Semi-major axis *a*	Semi-minor axis *b*	Inverse flattening (1/*f*)
GRS 80	6,378,137.0 m	≈ 6,356,752.314 140 m	298.257 222 101
WGS 84	6,378,137.0 m	≈ 6,356,752.314 245 m	298.257 223 563

WGS = World Geodetic System

More Details at

http://en.wikipedia.org/wiki/Figure_of_the_Earth

http://en.wikipedia.org/wiki/World_Geodetic_System#A_new_World_Geodetic_System:_WGS84

Density variations mean that there are discrepancies between the surface and the reference ellipsoid. A surface called the **geoid** takes this into account and will be discussed in B1.3.

Implications of a non-spherical Earth : Chimborazo in Ecuador is higher than Mount Everest, if measured from the centre of the Earth.